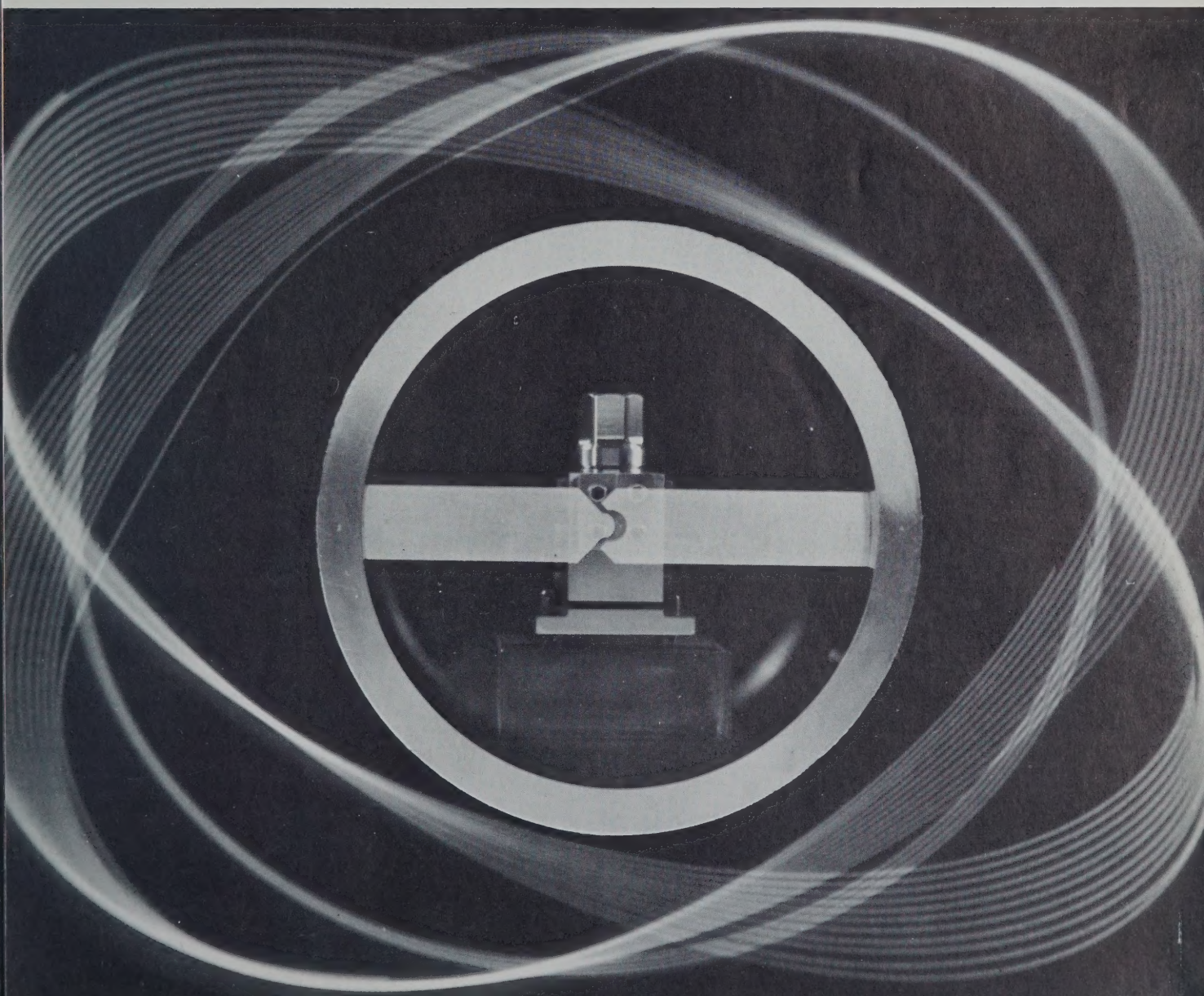
NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

VOLUME 45 JANUARY 1961 NUMBER 1



U.S. DEPARTMENT OF COMMERCE FREDERICK H. MUELLER, *Secretary*

NATIONAL BUREAU OF STANDARDS A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Subscription price, domestic $1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 24, 1958).

January 1961 Issued Monthly Vol. 45, No. 1

Contents

	Page
Measurement Research Conferences	1
Gallium Alloys for Low-Temperature Bonding	5
Program Announced for 1961 Temperature Symposium	7
Atomic Frequency Standards	8
Changes in WWV/WWVH Standard Broadcasts	11
The AMOS IV Computer for a Prototype Automatic Weather Station	13
Foote Named Coordinator of NBS Advisory Panels	15
Two Technical Advisory Committees Established	16
Announcement of New Publication: Precision Measurement and Calibration	17
Publications of the National Bureau of Standards	18

COVER: Deflecting magnet and source oven—the heart of the NBS atomic beam frequency standard. See "Atomic Frequency Standards," page 8.

Measurement Research Conferences

A SERIES of meetings between measurement specialists from member firms of the Aerospace Industries Association and NBS technical staff members has been held at the Bureau during the past several months, aimed at bringing into sharp focus the impact of the "measurement pinch" as it affects the aeronautical and missile industries. These Measurement Research Conferences, sponsored by the AIA, are a followup to the AIA Industry Calibration Survey, released in August 1959, which identified many specific areas in which the industry faced severe measurement problems.[1] Industry spokesmen have stated that the lack of national standards in many areas is causing confusion, excessive delays, and loss of money for both industry and the national defense program.

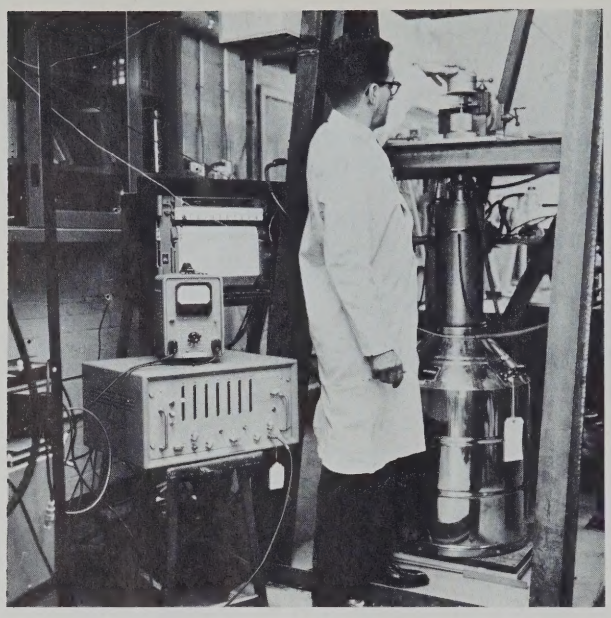
The Survey, suggested by the Air Force Air Materiel Command, was conducted by the AIA Quality Control Committee, with some technical advice from the Bureau. The replies, which were submitted anonymously, were very informative, but it seemed desirable to obtain more detailed information about the problem areas, and some indication of their relative importance.

Accordingly, a second survey, in April 1960, requested the AIA member companies to assign high, medium, or low priority to each specific problem area as it affected their own operations. They were also asked to name representatives from their firms to meet with NBS staff specialists. Thus far, eight of the Measurement Research Conferences have been held.

The attendees from industry have included project engineers, systems design engineers, and heads of standards laboratories. In each meeting, after somewhat formal presentations by the industry representatives, delineating the measurement problems and providing justification for their urgency, members of the Bureau staff have outlined related NBS capabilities and described the state of the art. The meetings have intentionally been kept small to permit and make effective open discussion periods after the formal presentations. The possibilities for short-range, interim solutions have been explored, as well as proposals for more adequate but longer-range solutions.

The AIA Measurement Research Conferences thus far have proved very valuable as they have focused attention on serious problem areas and have provided an opportunity for exchange of ideas and better understanding of the limitations under which measurement experts are working both in industry and at NBS. In some of the areas covered by these conferences, the Bureau has found it possible and has felt the justifica-

Kathleen Hannon assembles an experimental tantalum-tube high-temperature furnace. The furnace is used to calibrate refractory metal thermocouples at temperatures in excess of 2,000° C. A lack of standards for extremely high temperature measurements is a critical problem in space technology.



George Cataland measures the speed of sound in helium gas at 4 °K with an acoustical interferometer. The measurement is part of a Bureau program to establish an absolute temperature scale in the liquid helium region.

tion adequate to make program changes which will soon provide additional calibration services.

Additional meetings are planned for the future. The next series will deal with radiofrequency measurement problems and will be held at the NBS Boulder Laboratories in January. Tentatively scheduled for April is a series of meetings on shock, vibration, force, and acceleration. Other areas are scheduled for attention later in the summer.

Concurrently with the Measurement Research Conferences, the Bureau has taken steps to strengthen its technical publications program in the field of measurement. Now in press is a three-volume compilation of the Bureau's more important publications dealing with precision measurement and the calibration of standards. The publications were originally issued over a period of years as circulars, research papers, chapters of books, and articles in scientific periodicals, and, as separate documents, best served the needs of scientists working in specialized fields of measurement who hitherto made up the principal audience. Entitled "Precision Measurement and Calibration," this handbook will serve both as a "textbook" and a reference source for the many scientists and engineers who must be trained in the shortest possible time to fill responsible positions in this critical area.[2]

Microwave Power and Attenuation

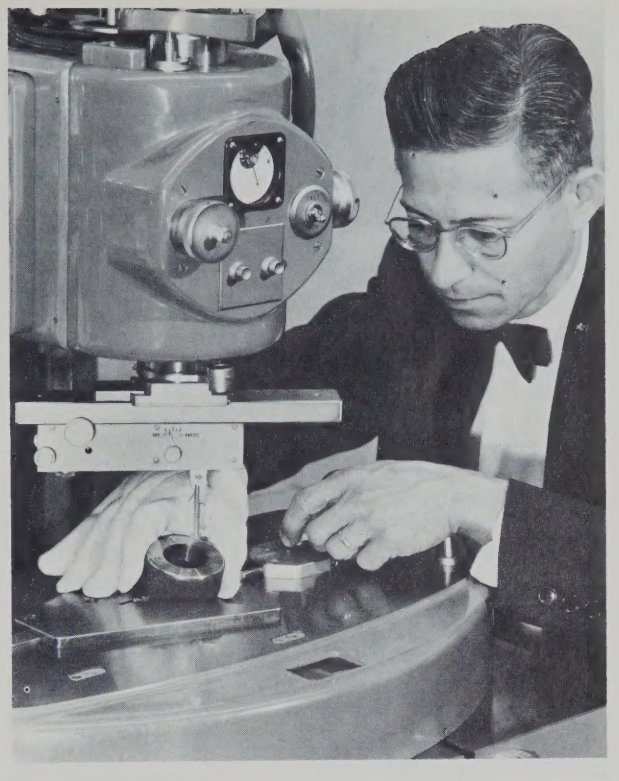
The first two meetings of this series were held at the Boulder Laboratories in May 1960 and dealt with microwave power and attenuation measurements. As an example of the needs in this area, an industry representative cited a million-dollar development of radomes which had to proceed more by trial and error than by test and analysis, because precise phase and amplitude measurement capabilities do not exist in the required frequency range. Another attendee cited the practice of over-design of Klystron tubes—devices used to generate high-power signals for radar detection systems—which is necessary to insure that the tubes are powerful enough to do the job. The availability of techniques for accurate measurements of peak microwave power would obviate the necessity for this costly procedure.

For these and some of the other expressed needs no immediate solutions seemed possible; however, in other cases interim solutions were suggested and are being adopted: e.g., calibration services for waveguide power measurements in the frequency range 3.95 to 8.2 Gc and coaxial power measurements in the frequency range 300 Mc to 12.4 Gc will soon be made available at NBS—albeit at somewhat lower accuracy than is considered ultimately necessary.

Internal Diameters and Surface Flatness and Finish

The second group of meetings was held at the Bureau's Washington laboratories in June and dealt with problems faced by industry in the measurement of internal diameters and of surface flatness and finish. The necessity for miniaturization imposed by space limitations in missiles and aircraft has caused a reduction in hole sizes with resulting calibration demands upon NBS in ranges lower than existing capabilities

Standards of surface finish are calibrated with this apparatus. The standard, on the anvil at left, has regularly spaced grooves of uniform depth. Frederic Harlee monitors the procedure. Insuring reliable gyroscope performance has been cited as typical of the problems directly related to measurement of surface finish characteristics.



Arthur B. Strang measures the roundness of a plain cylindrical ring gage. The calibration can be made within 2 millionths of an inch. Improved measurement techniques are expected to eliminate costly trial and error methods in the manufacture of precision components.

permit. During these meetings it became evident that inertial guidance systems and such developments as the use of gas bearings have resulted in requirements for extremely close tolerances which are directly related to product function. One industry representative claimed that if measuring techniques were available to permit holding the tolerances on bores and bearings to 10 microinches the cost of a large-quantity production item could be reduced from $950 to $250, and that, in the case of another item, lack of sufficiently accurate measurement capabilities of hole sizes is requiring the construction of three $25,000 units for every good one produced.

At this meeting there was a strong plea from the industry representatives for a research effort at NBS looking toward the development of standards and measuring techniques based, if possible, on entirely new concepts since it appears that time-honored procedures cannot provide the ultra-precise gaging which will permit the mass production with interchangeability of parts which is so essential in modern industry. At present industry is being forced back into the medieval concept of hand craftsmanship.

During the discussion of surface finish measurements the problem of noisy gyroscopes was given as an example. This type of faulty operation is believed to be associated with surface finish characteristics, since changing bearings or other frictional surfaces usually correct the difficulty. With existing standards and techniques it is not possible to measure surface characteristics with accuracy sufficient to eliminate defective components prior to assembly. Such trial-and-error methods are extremely costly in time and money.

As a partial solution to this latter problem, the Bureau will soon offer a calibration service for physical roughness standards, although the initially available accuracy will probably not meet all needs.

Gears

The fifth meeting, in September, was devoted to the problem of gear calibrations and measurements. Limitations in the use of master gears as standards were recognized; but at present this is apparently the only technique available for small gears and the industry representatives urged that NBS acquire the facility to provide a calibration service for such gears, and simultaneously organize a strong research program looking toward the development of better methods for standardizing gear measurements.

One industrial representative attending the meeting reported that, for the first six months of 1960, the cost of gears rejected by his company exceeded $54,000. This loss was the direct result of the absence of standard gear masters. In addition to these obvious losses, the company, because the high rejection rates resulted in sporadic deliveries, were forced to work their production facilities overtime at premium pay to fill their orders.

Infrared, Temperature and Humidity Measurements

The most recent series of meetings was held the latter part of October and dealt with infrared, temperature, and humidity measurements.

The need for specification of a "standard wet atmosphere" as a basis for evaluating the performance of infrared systems was stressed by several industry representatives. Serious difficulties have been encountered in attempts to get agreement between users and suppliers of infrared equipment because of the lack of agreement on test conditions. It was urged that the Bureau's current work in determining the molecular absorption properties of atmospheric constituents be continued at a high level as an effective contribution in this area. Programs in which radiometric measurements and decisions based on them must be made from satellites were cited as costly undertakings, the success of which is being periled by the lack of sufficiently accurate measurements and standards. It was also observed that several military systems are operating less reliably than is desirable because the decision-making functions are based on infrared measurements of inadequate accuracy.

Although the NBS program in temperature measurements and standards has nearly doubled in the last five

David Spangenberg is measuring the inside diameter of a plain cylindrical ring gage with a commercial machine which measures inside diameters of holes as small as .017 in. with an accuracy of a few millionths of an inch. Lack of suitable techniques for the measurement of internal diameters is a major problem in the production of inertial guidance systems, gas bearings, and other such devices.

years, it still is inadequate compared with the needs expressed by the industry members attending the meeting on temperature measurements. In the very-low-temperature region, where hydrogen and helium are liquids, extensive industrial use is being made of superconducting circuits and of cryogenic inertial reference systems. Temperature measurements in this region are being required with ever increasing accuracy.

As an example of measurement problems in the intermediate temperature range, an industry representative spoke of the necessity for precise temperature control within gyroscopes used in certain inertial reference systems. The system accuracy is strongly affected by the accuracy with which the temperature sensing and controlling elements function to maintain uniform performance of the gyroscope.

In the very-high-temperature region more accurate measurements are needed in the study of materials suitable for rocket throat lining. Rocket design engineers consider themselves seriously handicapped in their efforts to improve the design of rocket motors because standards and techniques for the measurement of exhaust gas temperatures are essentially non-existent. In this area the costs of improper design are large. For example, the cost of fuel alone in a single test firing of a certain rocket was stated as $125,000. The fact that even a small reduction in measurement uncertainties would reduce the number of test firings was repeatedly stressed.

An industry representative described an abort maneuver navigational system, for a glide-type re-entry vehicle, based on temperature measurements. He reported to the group that while the proposed technique appeared very attractive from every other consideration it had to be abandoned at the cost of increased complexity and reduced reliability because temperature measurements could not be made with the necessary accuracy.

It was pointed out that in many applications the cost of not having sufficiently accurate temperature measuring techniques available is actually far more serious when expressed in terms of months before check-out than in terms of dollars, although it is seldom possible to arrive at a definite estimate of the time factor.

Two examples were given relative to savings in weight in a missile system which could be achieved with a limited increase in the accuracy of temperature measurements. In one case, reduction of the uncertainty from 10 to 2 °F effected a savings of 250 lb with a substantial improvement in the range. In the other case it was demonstrated that improved temperature measurements available for determining the thermal conductivity of a heat shield would permit saving 125 lb in the payload which was translated into 12,500 lb in the complete system. Although accurate data on cost per pound for such a system were not available, possible savings were estimated at many thousands of dollars.

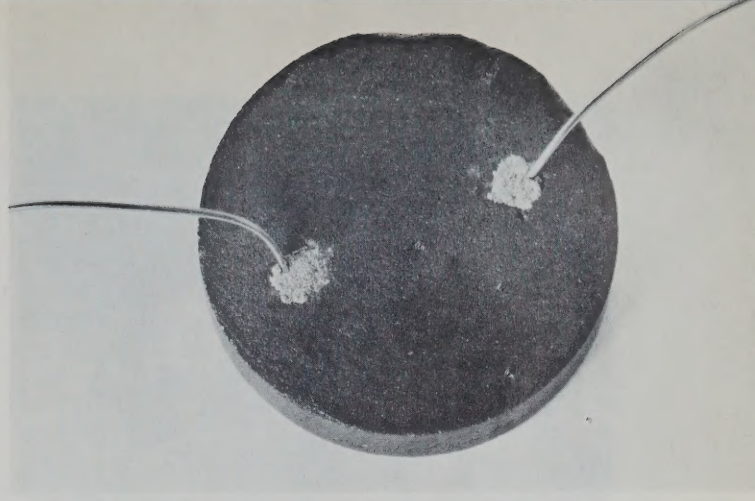
Many of the measurement problems discussed were related to difficulties associated with making measurements under non-ideal, field conditions. Although it was evident from the discussions that considerable competence exists at NBS in this area, it was likewise evident that available manpower and funds seriously limit the amount of assistance industry can expect from the Bureau. However, substantial contributions to the solution of some of the problems presented will be provided by two new services expected to be available from the Bureau by July 1961: calibration services for germanium resistance thermometers in the cryogenic region and for very-high temperature thermocouples.

---

[1] Standards and calibration activities in rapid growth, *NBS Tech. News Bul.* **43**, *221 (Dec. 1959)*.

[2] *The Superintendent of Documents, Government Printing Office (Washington 25, D.C.) is now accepting advance orders for NBS Handbook 77, "Precision Measurement and Calibration", Vol.* I, *"Electricity and Electronics" ($6.00); Vol.* II, *"Heat and Mechanics" ($6.75); and Vol.* III, *"Optics, Metrology, and Radiation" ($7.00).*

Gallium Alloys for Low-Temperature Bonding

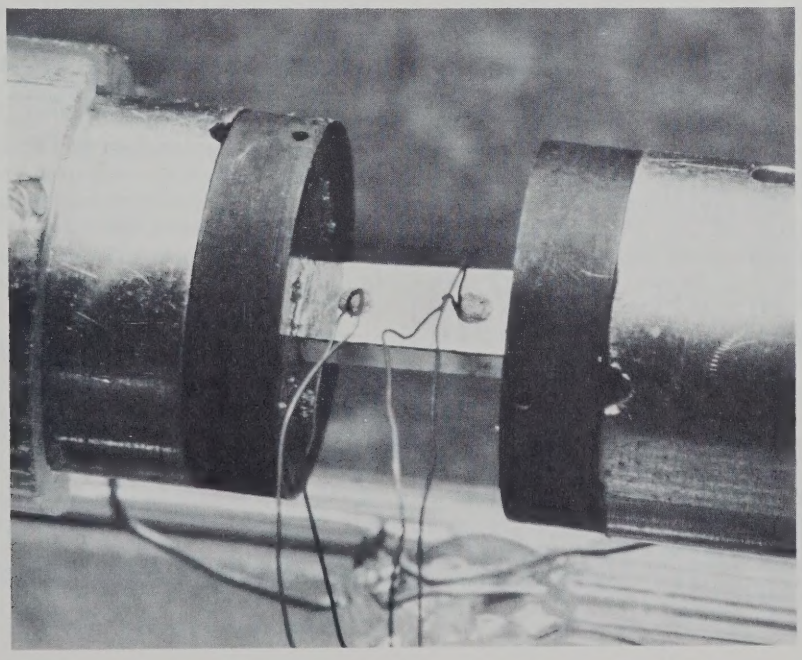


A gallium-gold alloy was used to fasten wires to a small, electrically conductive ferrite specimen. These alloys, developed by the Bureau, are soft when mixed at room temperature, and resist temperatures to 500 °C after hardening.

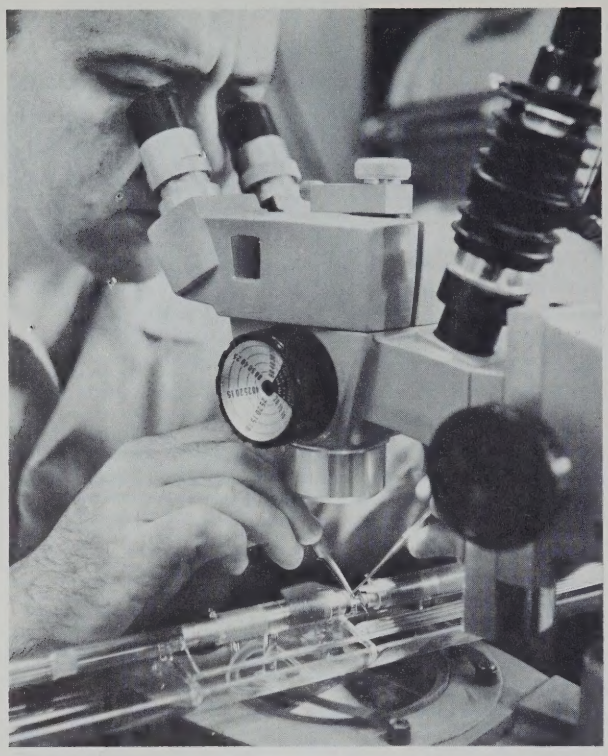
THE BUREAU, in a project sponsored by the Air Force, has been studying the use of gallium-based alloys as bonding materials. These alloys are soft when mixed at room temperature, but resist temperatures as high as 900 °C after hardening. G. G. Harman has found that they can be used to fasten wires to heat-sensitive electronic devices, such as transistors, and to "cold solder" ceramic and metallic surfaces.[1]

Like mercury, gallium will combine with many metals to form dental-type alloys which are soft at the time of mixing, and which harden after from 2 to 24 hr. These alloys were originally studied by the dental research laboratory [2,3] for use in dental restorations, but this use was discontinued when it was found that food would tarnish the alloys. Research by the electron devices laboratory indicated that the physical and electrical properties of gallium-based alloys would make them useful as bonding materials in electronic devices. Because the heat required in soldering operations is often sufficient to damage delicate electronic components, gallium alloys were employed to make the necessary connections, and proved entirely successful. Some ceramic and metallic surfaces can also be "cold soldered" by incorporating a layer of alloy between the surfaces being fastened.

To form gallium-based alloys, weighed portions of liquid gallium (mp 29.9 °C) and a finely powdered metal are thoroughly mixed in a Teflon beaker. After



Small platelet of silicon carbide (0.6 × 0.25 × 0.008 cm) mounted between 2 electrical contacts. Thermocouple leads have been attached to the sample with a gallium-copper alloy. The specimen is backed with a special glass, which provides mechanical support.



G. Harman positions a silicon carbide specimen in an apparatus designed to measure the thermoelectric power of this compound. Thermocouple leads have been attached to the specimen by means of a gallium-copper alloy.

several minutes' mixing, during which the gallium "wets" the other metal, the alloy is ready for use.

Various combinations of gallium with copper, gold, nickel, and silver were prepared and tested in this program. Tin was added to several of the gallium-copper alloys, and acted to delay the initial set. Practical batches as small as 0.1 g were prepared, which was sufficient to attach several electrodes to a surface. It was found that unused portions of gallium-gold alloys could be preserved for later use if refrigerated before hardening had occurred.

Expansion tests on various gallium alloys indicated that as much as 10 percent expansion may occur during hardening. This expansion is not of critical importance, however, as the soft-packed metal will generally compress itself rather than damage the material in which it is imbedded. The addition of aluminum oxide to gallium-gold alloys resulted in better bonding in cavities of barium titanate, perhaps by reducing the thermal expansion of the mixture.

The soft alloy is readily used to fasten wires to various devices. As an example of this application, a gold-

Properties of several gallium alloys [a]

Constituents in weight	Approx. hardening times at 25° C [b]	Maximum useful temperature in air [c]	Expansion coefficients and remarks
	hr	°C	
1. 44% Cu+24% Sn, 32% Ga	24	650	$\alpha=23.7\times10^{-6}$ °C after heating
2. 50% Cu+18% Sn, 32% Ga	24	700	$\alpha=23.1\times10^{-6}$ °C after heating
3. 66% Cu+34% Ga	4	900	$\alpha=19.5\times10^{-6}$ °C after heating
4. 82% Au+18% Ga	5	450	
5. 66% Au+34% Ga	8	525	$\alpha=(15+0.012T)\ 10^{-6}$ °C
6. 59% Au+41% Ga	8	475	
7. 33% Au+33% Cu+33% Ga.	8	650	
8. 49% Au+21% Ag+30% Ga.	2	425	
9. 65% Ni+35% Ga	48	250	Becomes a black powdery mass above this temperature
10. 52% Ag+48% Hg	3	900	Contracts while hardening
11. Au, Ag, Co, Cu, Ni, Sn	These metals and possibly many others may be added in varying amounts to the gallium alloys to change the setup time and/or the thermal expansion		

[a] All of these alloys, except No. 10, expand as they harden, thus locking themselves into the semi-conductor.

[b] These values assume a particle size to pass through ~300 mesh screen. Larger particle sizes may take longer. Setup times at higher temperatures will be considerably less. Five or ten minutes will usually suffice at 200 °C. At this temperature the Au-Ga mixture produces an exothermic reaction.

[c] The actual melting point is about 25 °C higher than the temperatures given in this column. These temperatures are only reproducible to ±15 °C because some of the fine metal powder usually sticks to the mortar or is not properly wet by the gallium.

gallium-tin alloy was used to attach thermocouples to power transistors. Small holes were drilled in the transistor cases to receive the wires. Fine wires were then inserted in the holes, and the alloy was packed in with dental tools. After a period of hardening the connection was ready for use. Wires that react with gallium, such as gold, cannot be fastened by this process, as they become brittle and snap. Also, for best results the wires used should be between 0.01 and 0.03 in. in diameter.

The alloys can also be used to cold solder various materials. This process once again offers the advantages of low-temperature formation and high-temperature strength. Pieces to be fastened together are positioned with a layer of alloy sandwiched between, and pressure is applied until the alloy has hardened. If no reaction occurs between the alloy and the materials being joined the bond is purely mechanical, and the bond strength depends upon the roughness of the surfaces involved. With some materials, such as copper, a reaction may occur between the alloy and the pieces being joined, and a stronger bond will result.

By using higher formation temperatures, cold soldering may be extended to include a wide variety of metals and alloys. For example, a finely-powdered mixture of indium and gold could be placed between the surfaces to be joined, and the whole assembly heated until the indium melts (155 °C). At this temperature an alloy would be formed with the gold, which, after hardening under pressure, would form a joint that can withstand a much higher temperature (about 500 °C) than the indium metal alone. Cold soldering is a relatively new phase of this investigation. A proposal has been made that further work be initiated to extend the useful range of this technique.

---

[1] Hard gallium alloys for use as low contact resistance electrodes and for bonding thermocouples into samples, *George G. Harman, Rev. Sci. Instr.*, **31**, *717 (July 1960)*.

[2] Alloys of gallium with powdered metals as possible replacement for dental amalgam, *D. L. Smith, H. J. Caul, J. Am. Dental Assoc.*, **53**, *315 (Sept. 1956)*.

[3] Some physical properties of gallium-copper-tin alloys, *D. L. Smith, H. J. Caul, W. T. Sweeney, J. Am. Dental Assoc.*, **53**, *677 (Dec. 1956)*.

Program Announced for 1961 Temperature Symposium

THE technical program is now complete for the most comprehensive meeting ever held on the subject of temperature measurement. About 200 papers will cover temperature measurements from absolute zero to 10,000 °K with interests ranging from the temperature of the human body to the temperature of the sun. Almost every area of the physical, biological, and medical sciences will be represented at the 1961 Symposium on "Temperature, Its Measurement and Control in Science and Industry," to be held in Columbus, Ohio, March 27 to 31, 1961. The conference is sponsored by the American Institute of Physics, the Instrument Society of America, and the National Bureau of Standards.

Temperature ranks as one of the most important of the physical quantities, and its measurement and understanding have provided some of the most difficult and challenging problems in experimental and theoretical physics. The 200 papers scheduled for presentation come from universities, government and military research laboratories, and industrial research laboratories in this country, as well as from research centers in Australia, Germany, Netherlands, Canada, Soviet Russia, and Great Britain.

The symposium is organized into 16 sessions, devoted to such topics as: Basic Concepts of Temperature, Temperature Scales, Thermocouples, Resistance Thermometers, Gas Thermometers, Spectroscopic Methods, Pyrometry, Miscellaneous Methods, Automatic Methods for Measurement and Control, Measurement in Dynamic Systems, Special Sources of Temperature, Cryogenics, Plasmas, Temperature Measurement in Geophysics, Temperature Measurement in Astrophysics, and Temperature Measurement in Biophysics and Medicine.

Some of the most recent advances in high temperature and low temperature measurements will be described in the papers delivered at the symposium. Interest in the higher regions is sparked by the great efforts being made in plasma physics. At the lower end of the scale, there is great interest in extending the International Practical Temperature Scale down to the region of 1 °K.

Three international symposia have previously been held to permit exchange of information among the various groups that work with extreme temperatures and precision temperature measurement, and to stimulate research pertinent to these fields of interest. The first symposium was held in Chicago in 1919. The second meeting was held in New York City in 1939, and its proceedings were published under the title *Temperature, Its Measurement and Control in Science and Industry* (Reinhold, New York, N.Y., 1941). The third meeting, in 1954, dealt with fundamental concepts and summarized the developments that had taken place since 1939. The proceedings of these symposia, *Temperature, Its Measurement and Control in Science and Industry*, published by Reinhold, New York, N.Y., have become basic reference works in the field.

Persons interested in the symposium may obtain further information by writing to V. W. Sikora, Instrument Society of America, 313 Sixth Ave., Pittsburgh 22, Pa.

578342 O - 61 - 2

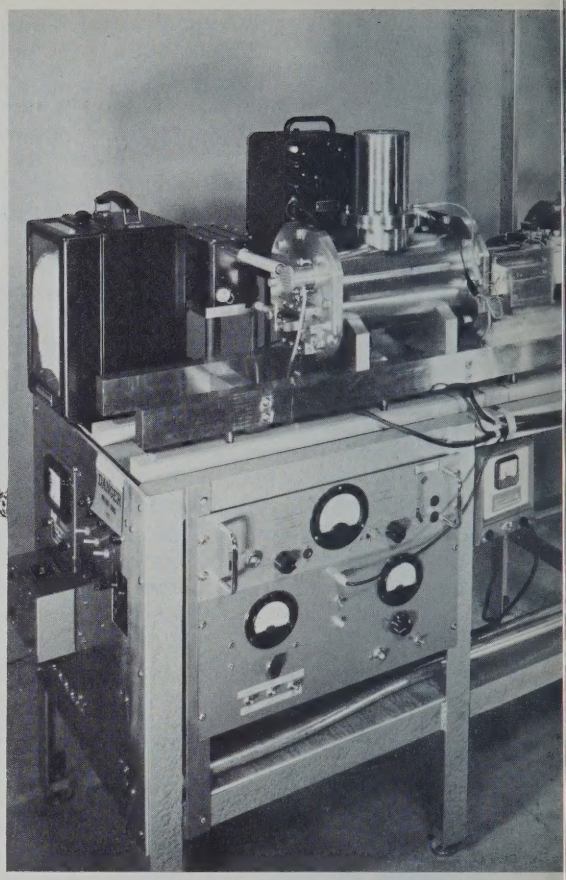
IN RECENT YEARS, the Bureau has been conducting developmental research on the precise measurement of frequency. For radio communications, the tracking of satellites, the control of long-range rockets, and astronomical observations, timing accuracies of one part in a billion or better will be required in the future. Many scientific activities rely on regular radio transmissions of standard frequencies from Bureau stations WWV, WWVB, and WWVH and from the Navy's NBA to provide high accuracies. These broadcasts are based on astronomical observations related to the earth's rotation as made by the U.S. Naval Observatory. However, to meet the ever-increasing need for even greater accuracy, the Bureau has been investigating atomic frequency standards, [1, 2, 3] which are potentially three orders of magnitude more precise for time-interval determinations than the rotation of the earth.

Over the past several months comparisons have been made between two dissimilar cesium-beam atomic frequency standards constructed at the NBS Boulder Laboratories. The devices were tested independently, the pertinent parameters measured, and frequency comparisons subsequently made. The results of the experiments, carried out by R. C. Mockler, R. E. Beehler, and C. S. Snider, demonstrate that beam devices of rather modest length (55 cm between the oscillating fields for the shorter machine) can have precisions of ± 2 parts in 10^{12} for measurement periods of one to a few hours. The frequency difference between these two machines is 1.0×10^{-11}. This frequency difference has remained within $\pm 2 \times 10^{-12}$ over the last 9 months. Greater accuracy, by at least an order of magnitude, should be attainable with some improvements in the apparatus.

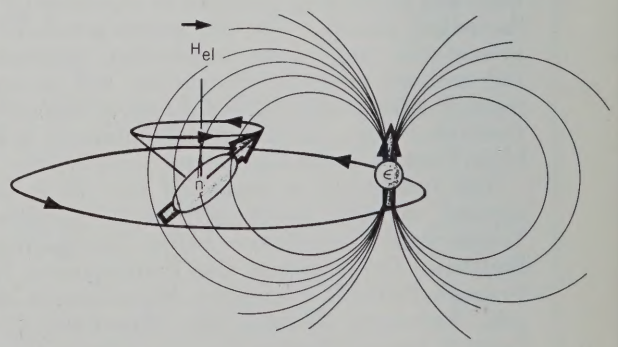
At the present time, radio transmissions controlled by the Bureau's master quartz-oscillators are being monitored with the cesium beam frequency standards. Corrections for the 60-kc/s standard frequency broadcasts from NBS radio station WWVB (formerly KK2XEI) at Boulder, Colo., are being made each week and are available on request from the Broadcast Services Section at the Bureau's Boulder Laboratories. Corrections for the 20-kc/s transmission from NBS station WWVL will be available shortly.

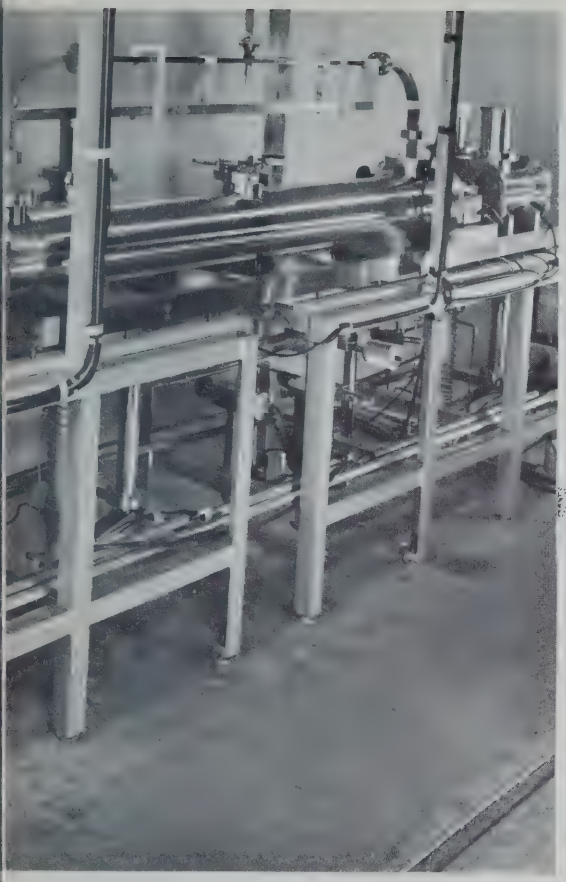
Until the development of atomic frequency standards, the most uniform time-intervals available were those derived from astronomical observations of the rotation of the earth relative to the fixed stars corrected to the orbital motion of the earth about the sun. This orbital motion of the earth is the basis of Ephemeris Time. It has been measured with a probable error of 2 parts in 10^9 in a period of 3 years. Higher precision is expected for longer measurement times. In 1956, the second of Ephemeris Time was adopted as the fundamental unit of time by the International Committee of Weights and Measures and this action was confirmed by the General Conference on Weights and Measures in 1960. Steps were taken by the Conference toward the adoption of an atomic standard for time-interval.

A time scale approximating Ephemeris Time can be made immediately available by the use of atomic stand-

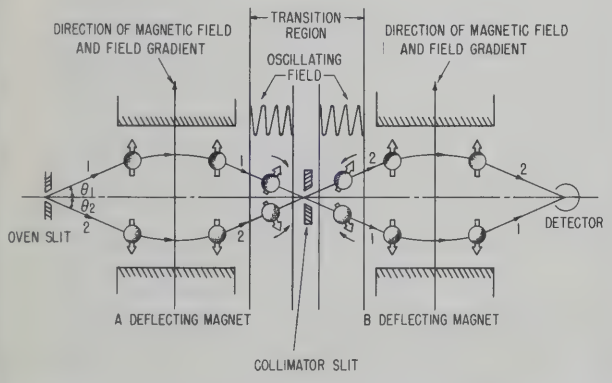


atomic fr
stand





equency
lards



ards, quartz oscillators, and counters. In terms of the Ephemeris second, the frequency of the cesium transition is experimentally found to be 9,192,631,770±20 c/s.[4] The probable error, ±20 c/s (or 2 parts in 10^9), results from the limitations on the precision of the astronomical measurements. The frequency of the transition is assumed to be exactly 9,192,631,770 c/s for the purpose of maintaining constancy of broadcast frequencies.

Measurement of a frequency or a time interval in terms of the cesium transition can be made with a precision of ±0.2 c/s and is not limited by the instrumental difficulties involved in astronomical observations. However, it does not supplant the present definition of a scale for time based on the uniform apparent motion of the sun.

It seems natural to base the standard of time-interval on the physical process or experimental technique that provides the most uniform and most accessible interval. The precision of measurement for the atomic standards is two orders of magnitude better over a 2-min period than astronomical measurements made over a period of 3 years.

Also under investigation as a standard of frequency is the thallium atom, which has certain significant advantages over the cesium atom in this application. However, thallium may have some disadvantages in practical use. A thallium beam is now being placed in operation at the Boulder Laboratories to determine which of the two atomic techniques is the more suitable.

The cesium beam frequency standard is essentially an atomic beam spectrometer excited by a crystal oscillator driving a frequency multiplier chain. The spectrometer puts out a signal only when the excited atoms go through a quantum transition. The exciting signal from the frequency multiplier chain is designed to have a frequency very nearly equal to this transition frequency. Therefore, if there is an output from the spectrometer when it is excited by this signal generator, the frequency of the generator must be the same as the transition frequency of the cesium atom.

In practice, the signal generator is manually or automatically varied over a narrow band to find the "center" frequency, and when the spectrometer output is at a peak, the signal generator frequency is known within ±0.2 c/s or two parts in 10^{11}. Suitable automatic equipment could be used to control the signal generator so that the spectrometer output would stay at the maximum, thus providing a signal of known and nearly constant frequency for as long as the device can be kept running. As the separations of the quantum states of an isolated atom are constant with time, they

---

Top: NBS-II Atomic Beam Frequency Standard. The separation between the oscillating fields inducing the atomic transition is 164 cm. The spectral line width is 90 to 140 cps. Below, left: Precessional motion of the cesium nucleus in the strong magnetic field produced by the valence electron. Below, right: Schematic of an atomic beam spectrometer. The trajectories are drawn for those atoms whose magnetic moments are "flipped" in the transition region.

can be expected to provide a stable, reproducible standard of frequency and time interval when the atomic beam resonance technique is used.

The atomic beam magnetic resonance technique introduces the smallest perturbation on the atomic system of the presently known techniques. This small perturbation is important because the presence of the measuring apparatus introduces an uncertainty in the measurement. Although the state separations are time invariant for an isolated atom, the atoms are no longer completely isolated when observations are being made.

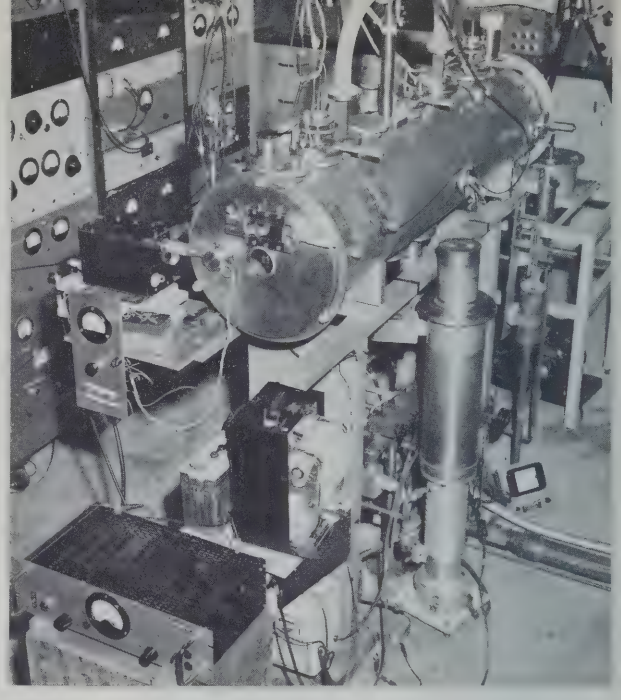
The most precise measurements of quantum state separations can be made for those energy levels in the ground electronic state of atoms and molecules. For a standard of frequency, it is important to choose a quantum transition of high frequency, within the scope of existing coherent radiators, and of high intensity, for the sake of precision in measurement. Reducing line breadth due to collisions between the atoms and line broadening due to the Doppler effect is important. The transition in cesium between two hyperfine structure levels in the ground state satisfies these requirements.

This hyperfine splitting of the ground state is due to the interaction between the magnetic moment of the nucleus and the magnetic field produced by the valence electron at the position of the nucleus. The nuclear dipole moment may be pictured as precessing rapidly in the relatively large field supplied by the electron as shown (see drawing, preceeding page). One group of the hyperfine structure levels is associated with one direction of the electron dipole moment (or spin) and the other group of levels is associated with the opposite direction of spin orientation. If the atom makes a transition from the upper of the two levels to the lower, a quantum of energy is released. In the reverse process, a quantum of energy is absorbed.

An atomic beam spectrometer is shown in the photograph on the preceeding page. Neutral atoms effuse from the oven and pass through the non-uniform magnetic field of the deflecting magnet. As the atoms have a magnetic dipole moment, a transverse force will act upon them in this non-uniform field. The magnitude and direction of this force depend upon which of the states the particular atom is in. Of all the atoms effusing from the oven at angle θ_1 and speed v, suppose those in the upper group of hyperfine levels (electron spin up)* have their trajectories bent toward the axis and follow the path 1. All atoms in the lower group of states (spin down) effusing at angle $\theta_2 = -\theta_1$ and speed v will have their trajectories bent toward the axis also and follow a trajectory along path 2. Note that atoms with upward spins and those with downward spins experience forces in opposite directions. The upward-spin atoms traversing trajectory 1 and the downward-spin atoms traversing trajectory 2 will cross the axis at the collimator slit, pass through the slit, and enter the region of the B deflecting magnet.

As the B magnetic field is exactly like that of the A magnet, it exerts the same transverse force on the atoms as does the A magnet field. The upward-spin atoms will experience a downward force as before and the downward-spin atoms will be acted on by an upward force, as before. As the two sets of atoms are now on opposite sides of the center line of the machine, these forces will tend to make their trajectories more divergent from the center line. However, if a radiation field is applied at just the proper frequency ν_0 (where $h\nu_0$ is the energy separation of 2 of the quantum states) to induce transitions between 2 of the states in the region between the A and B magnets, the spins will be reversed for those 2 states, and a quantum of energy ($h\nu_0$) will be either emitted or absorbed. Since the sign of the magnetic moment has changed in moving from the A magnet to the B magnet, the force on these atoms will reverse its direction and the atoms will be refocused onto the axis at the detector. Thus, as the exciting radiation is swept in frequency, the detected signal will increase and reach a maximum at ν_0 and then decrease as the radiation frequency is varied beyond ν_0.

*It is assumed that the deflecting fields are strong fields for the purpose of qualitative discussion.



NBS-I Atomic Beam Frequency Standard. The separation between the oscillating field inducing the atomic transitions is 55 cm. The spectral line width is 250 to 300 cps.

[1] The cesium resonator as a standard of frequency and time, *by L. Essen and J. V. L. Parry, Phil. Trans. Roy. Soc., London,* **A250**, *45 (1957).*

[2] Comparison and evaluation of cesium atomic beam frequency standards, *by J. Holloway, W. Mainberger, F. H. Reder, G. M. R. Winkler, L. Essen, and J. V. L. Parry, Proc. IRE* **47**, *1732 (1959).*

[3] A comparison of atomic beam frequency standards, *by R. E. Beehler, R. C. Mockler, and C. S. Snider, Nature* **187**, *681 (August 20, 1960).*

[4] Frequency of cesium in terms of Ephemeris Time, *by W. Markowitz, R. G. Hall, L. Essen, and J. V. L. Parry, Phys. Rev. Letters* **1**, *106 (1958).*

Changes in WWV/WWVH Standard Broadcasts

ON January 1, 1961, at 0000 UT, the Bureau retarded the time signals broadcast from radio stations WWV and WWVH by 5 msec,[1] and at the same time resumed broadcasting a special timing code[2] which gives the day, hour, minute, and second (UT) coded in binary form. The 5-msec retardation brought the time signals of WWV/WWVH into closer agreement with other standardized frequency broadcasting stations throughout the world. The pulse timing code, tried out on an experimental basis for several months during 1960, has now been returned to the air on a permanent basis.

Time Signal Adjustment

The United Kingdom and the United States began coordinating their time and frequency transmissions early in 1960. This coordination is the result of an agreement announced by Dr. James H. Wakelin, Jr., Assistant Secretary of the Navy (Research and Development), Dr. Allen V. Astin, Director of the U.S. National Bureau of Standards, and in the United Kingdom by the Astronomer Royal, Royal Greenwich Observatory, and the Director of the National Physical Laboratory.

Coordination was begun to help provide a more uniform system of time and frequency transmissions throughout the world, needed in the solution of many scientific and technical problems in such fields as radio communications, geodesy, and the tracking of artificial satellites.

Participating in the project are the Royal Greenwich Observatory, the National Physical Laboratory, and the Post Office Engineering Department in the United Kingdom, and, in the United States, the U.S. Naval Observatory, the Naval Research Laboratory, and the National Bureau of Standards. This program follows previous cooperative efforts of these agencies to achieve uniformity and simplification in procedures.

The transmitting stations which are included in the coordination plan are GBR and MSF at Rugby, England; NBA, Canal Zone; WWV, Beltsville, Maryland; and WWVH, Hawaii.

Although the signals emitted by all these stations are kept on as uniform a basis as is feasible, occasional corrections are necessary. The last previous time adjustment for WWV/WWVH, a retardation of 20 msec, was made on December 16, 1959. It is expected that such adjustments in the time signals will be made as infrequently as possible and preferably at the beginning of each calendar year when necessary. The time signals are locked to the broadcast frequency.

In 1961 it is planned to maintain the frequency stable to 1 part in 10^{10} and at the same offset value as before, i.e., -150 parts in 10^{10} with reference to the United States Frequency Standard.[3]

Timing Code

The timing code provides a standardized timing basis for use when scientific observations are made simultaneously at widely separated locations. It can be used for example, where signals telemetered from a satellite are recorded along with these pulse-coded time signals; subsequent analysis of the data is then aided by having unambiguous time markers accurate to a thousandth of a second. Astronomical observations may also benefit by the increased timing potential provided by the pulse-coded signals.

Description of Time Code on WWV

This 36-bit, 100-pulse/sec time code, carried on 1,000–c/s modulation, is being broadcast from radio station WWV (2.5, 5, 10, 15, 20, and 25 Mc/s). Starting date was January 1, 1961.

1. The code is broadcast for 1-min intervals and 10 times per hour. Except at the beginning of each hour, it immediately follows the standard audiofrequencies of 440 c/s and 600 c/s.

2. The code contains time-of-year information (Universal Time) in seconds, minutes, hours, and day of year. It is locked in phase with the frequency and time signals.

3. The code is binary coded decimal (BCD) consisting of 9 binary groups each second in the following order: 2 groups for seconds, 2 groups for minutes, 2 groups for hours, and 3 groups for day of year. Code digit weighting is 1–2–4–8 for each BCD group multiplied by 1, 10, or 100 as the case may be.

4. A complete time frame is 1 sec.

5. The least significant binary group and the least significant binary digit in each group occur first. The binary groups follow the 1-sec reference marker.

6. "On time" occurs at the leading edge of all pulses.

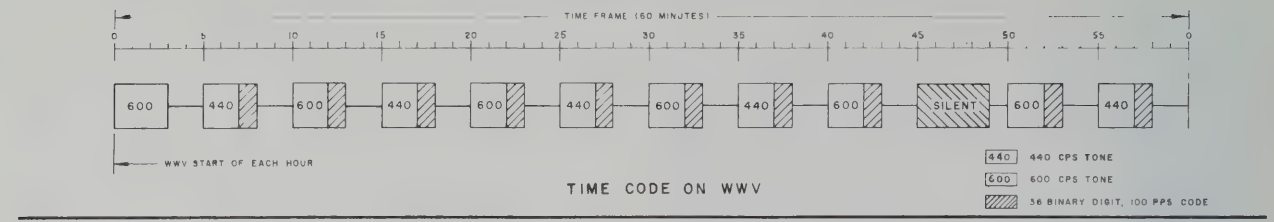
7. The code contains 100-per-second clocking rate, 10-per-second index markers, and 1-per-second reference marker. The 1,000 c/s is locked to the code pulses so that millisecond resolution is easily obtained.

8. The 10-per-second index markers consist of "1" pulses preceding each code group except at the beginning of the second where it is a "0" pulse.

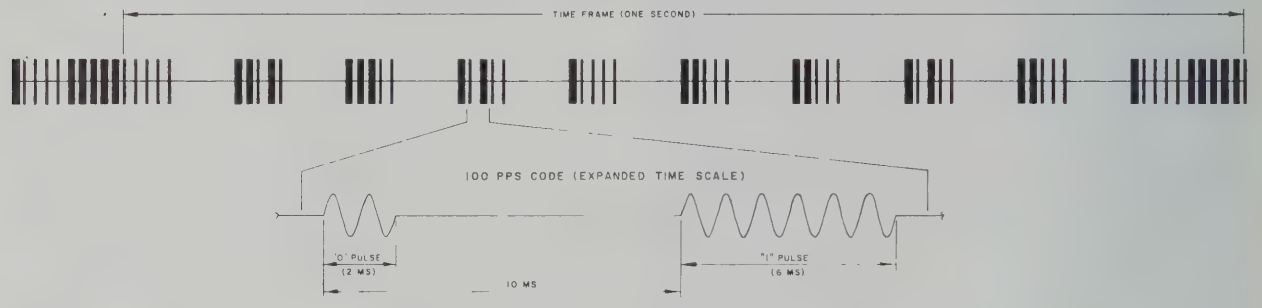
9. The 1-sec reference marker is made up of five "1" pulses followed by a "0" pulse. The second begins at the leading edge of the "0" pulse.

10. The code is a spaced code format; that is, a binary group (BCD) follows each of the 10-per-second index markers. The last index marker is followed by

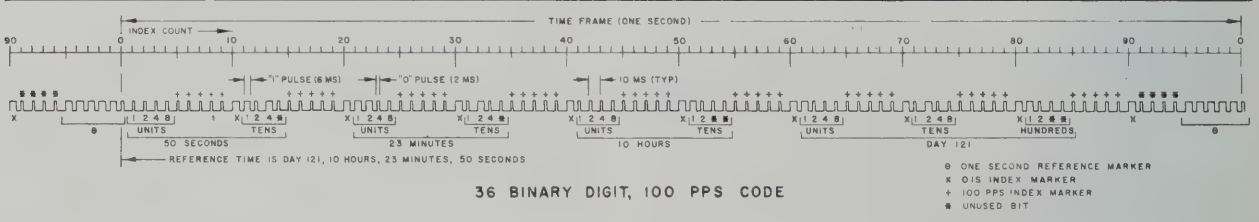
Chart of time code transmissions from NBS radio station WWV.



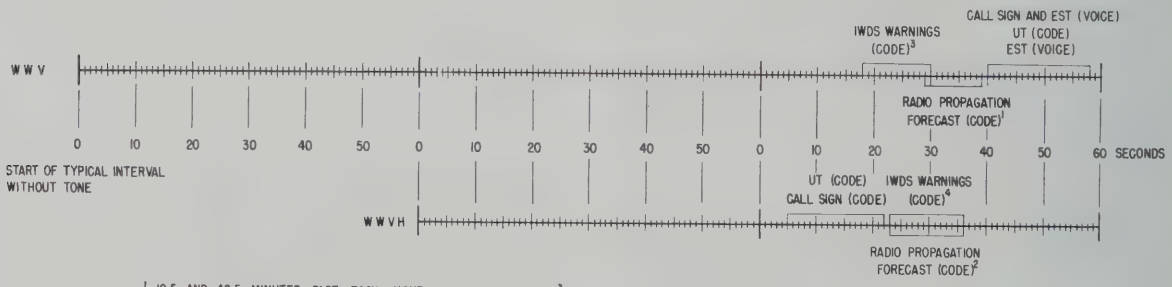
TIME CODE ON WWV



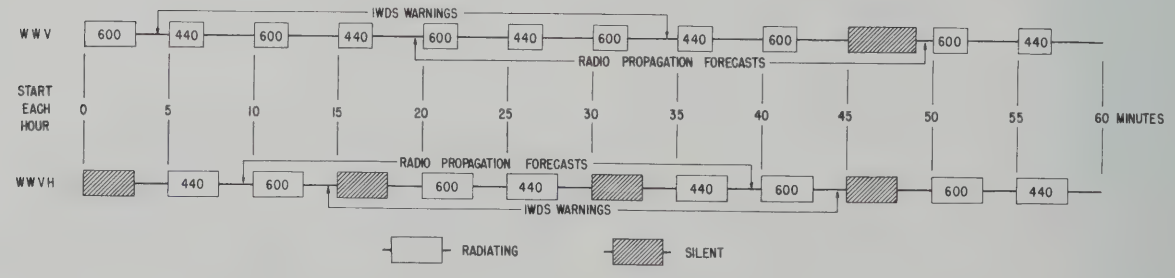
36 BINARY DIGIT, 100 PPS CODE (1000 CPS CARRIER)
(WITHOUT 100 PPS INDEX MARKERS)

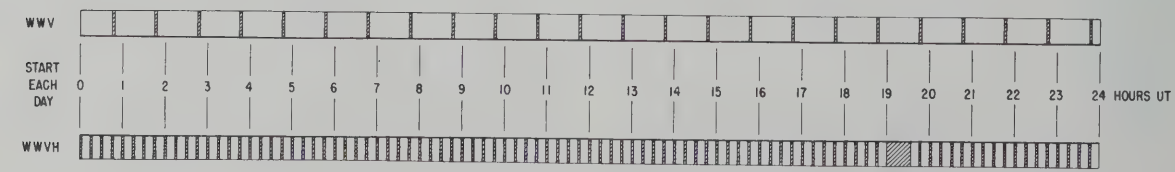


36 BINARY DIGIT, 100 PPS CODE


WWV
IWDS WARNINGS (CODE)3
CALL SIGN AND EST (VOICE)
UT (CODE)
EST (VOICE)
RADIO PROPAGATION FORECAST (CODE)1
0 10 20 30 40 50 0 10 20 30 40 50 0 10 20 30 40 50 60 SECONDS
START OF TYPICAL INTERVAL WITHOUT TONE
UT (CODE)
GALL SIGN (CODE)
IWDS WARNINGS (CODE)4
WWVH
RADIO PROPAGATION FORECAST (CODE)2

1 19.5 AND 49.5 MINUTES PAST EACH HOUR
2 9.4 AND 39.4 MINUTES PAST EACH HOUR
3 4.3 AND 34.3 MINUTES PAST EACH HOUR
4 14.4 AND 44.4 MINUTES PAST EACH HOUR


IWDS WARNINGS
WWV
600 440 600 440 600 440 600 440 600 600 440
RADIO PROPAGATION FORECASTS
START EACH HOUR
0 5 10 15 20 25 30 35 40 45 50 55 60 MINUTES
RADIO PROPAGATION FORECASTS
WWVH
440 600 600 440 440 600 600 440
IWDS WARNINGS
RADIATING
SILENT



an unused 4-bit group of "0" pulses just preceding the 1-second reference marker.

11. The unused 4-bit group may be used in the future to transmit other types of coded information, such as the last digit of the year, station number, etc.

12. Width coding:

"0" pulse, 2 msec wide (2 cycles of 1,000 c/s)
"1" pulse, 6 msec wide (6 cycles of 1,000 c/s)

13. The time code is amplitude modulated on 1,000 c/s. The leading edges of the time code pulses coincide with a positive-going zero-axis-crossing of the 1,000 c/s.

[1] National standards of time and frequency in the United States, *Proc. IRE* **48**, *105–106 (Jan. 1960)*.

[2] Experimental timing code added to WWV broadcasts, *NBS Tech. News Bul.* **44**, *114 (July 1960)*.

[3] Atomic frequency standards, *NBS Tech. News Bul.* **45**, *8 (Jan. 1961)*.

For additional technical information see Standard frequencies and time signals from NBS stations WWV and WWVH, *NBS Misc. Publ. 236, available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price: 10 cents.*

The AMOS IV Computer for a prototype automatic weather station

THE BUREAU, in cooperation with the U.S. Weather Bureau, has developed a specialized digital computer [1] for the Weather Bureau to use as a research tool in exploring the concept of the automatic weather station. The AMOS IV computer receives data from weather-sensing instruments and processes these data through such functions as sampling, comparing, selecting a maximum, and arithmetic operations. The results are transmitted via teletype to a central forecasting station and to other airport weather stations. Values of two quantities recently developed as aids to air safety—runway visual range and approach light contact height—are given by the machine through automatic table look-up.

For a number of years the Weather Bureau has been appraising the possibilities of an automatic weather station. Such stations could be widely distributed, and would be especially useful in relatively inaccessible locations that are important sources of early data on meteorological activity. The various developmental prototypes of this concept have been called AMOS (Automatic Meteorological Observation Station); the current version, containing transistorized packages, is AMOS IV. This model was designed and built by Paul Meissner and J. A. Cunningham of the NBS data processing systems laboratory and by C. A. Kettering of the U.S. Weather Bureau. It is an outgrowth of previous work done by NBS for the Weather Bureau that resulted in a special computer [2] for processing cloud-height signals from a ceilometer. The ceilometer was intended for use with the AMOS III.

Several of the input quantities to the AMOS computers, such as cloud height and precipitation, cannot be satisfactorily represented by instantaneous values but must be time-averaged. Varying amounts of data

Overall view of the prototype AMOS IV computer. Inset: One of the drawers of transistorized plug-in package assemblies (at left in large picture).

processing must therefore be associated with the different instruments measuring these quantities. In the AMOS III concept, several complex units were required for these functions. Although many of the functions were similar, the hardware was not minimized because of a diversity of design that resulted from the isolated development of the individual units. Analysis of the overall system indicated that a considerable reduction could be made in hardware and therefore in maintenance.

In AMOS IV, the automatic weather station is built around a single small, general-purpose computer designed especially for this application. The computer receives data from the input instruments at any desired interval. These data are suitably processed and arranged in a specified order for teletype transmission in a variety of message formats and at various speeds. The computer also operates local and remote displays. Much latitude is available for research into the most desirable form of data processing because of the inherent flexibility of the internally programed machine.

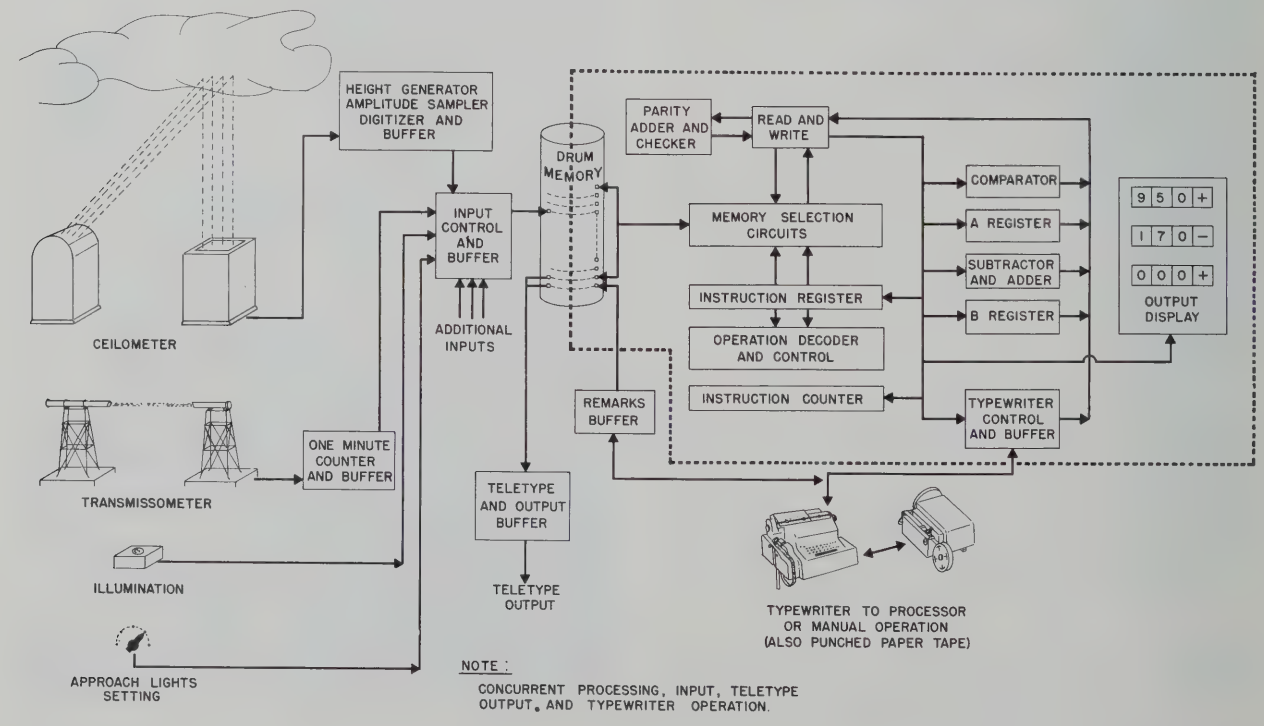
The computer continuously monitors new input data while simultaneously processing data already entered and transmitting messages on command. Among the input quantities which the AMOS IV computer can handle are temperature, dewpoint, wind speed and direction, atmospheric pressure, precipitation, transmissivity, and cloud height. Input data can be received directly from the instruments in the simplest possible form, such as analog voltage, current, or resistance; and pulse rate or contact closure. Information may also be received in coded form, such as the Gray binary code frequently used with shaft-position encoders. The nature of the weather instruments and of the quantities measured limits the input data to two or three decimal digits for the most part; word size is therefore three digits plus sign. Double-precision methods are available for those few instances requiring greater accuracy. Communication with the machine is via electric typewriter or punched tape.

The computer circuitry is based on transistorized plug-in assemblies [3] designed at the Bureau for a variety of data-processing applications. These 50-kc/s packages perform flip-flop, analog switch, and gating circuitry functions, as well as others.

To store data, the machine uses a magnetic drum operating at 1,800 rpm that carries 100 general storage channels of 100 words each and has space for 100 additional channels. Several dual-head channels are availble for simultaneous read-in and read-out of incoming data, outgoing messages, etc. The magnetic drum provides the extensive storage capacity required for the table look-up involved in the calculations of runway visual range and approach light contact height. About 35 tables are stored on the drum; each table has about 90 three-digit values.

One set of these tables contains the data on runway visual range (RVR), i.e., the distance along the runway visible to a pilot from the point of touchdown—generally 1,000 to 6,500 ft, depending upon runway illumination (natural and artificial) and atmospheric conditions. The primary input for the RVR determi-

Block diagram of the AMOS IV computer operation including the sensing instruments that furnish input data for the determination of the approach visibility.



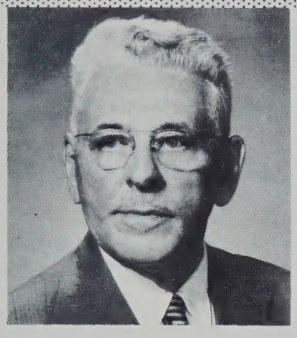
nation is a transmissometer reading. The computer continuously monitors this reading and "looks up" the proper corresponding value of RVR, which is then displayed locally and inserted into the teletype message.

The other set of tables contains the data on approach light contact height (ALCH), i.e., the height from which the pilot can identify the approach lights. ALCH is affected by background illumination level, atmospheric conditions, and the intensity of the approach lights, which are set in accordance with prevailing conditions. If limiting conditions are indicated by either low clouds, as shown by the ceilometer, or by fog or snow, as sensed by the transmissometer, a value of ALCH based on the interfering factor is obtained. If both factors are present, two calculations are made; the machine then determines and displays the lower value. Since there is a statistical uncertainty in this type of information, two values of altitude are presented. The higher altitude is that at which the pilot has a 20-percent probability of seeing the approach lights; the lower altitude is that at which the probability is 90 percent.

[1] A computer for weather data acquisition, *by P. Meissner, J. Cunningham, and C. Kettering, Proc. EJCP* **18,** 57 (Dec. 1960).

[2] Cloud-height data analyzer, *NBS Tech. News Bull.* **43,** *180 (1959).*

[3] Packaged switching circuits, *NBS Tech. News Bull.* **43,** *184 (1959).*



Foote Named Coordinator of NBS Advisory Panels

DR. Paul D. Foote, former Assistant Secretary of Defense for Research and Engineering, and a scientist of national prominence, has recently been appointed by the National Academy of Sciences to coordinate the work of the Academy's advisory panels for the Bureau.

The appointment represents the expressed desire of the National Academy of Sciences-National Research Council to give strong leadership to the activities of the Technical Advisory Panels.

For Dr. Foote, whose official title is Executive Secretary of the NAS-NRC Technical Advisory Panels for the National Bureau of Standards, the new appointment represents a return to the scene of his first job, after a third of a century. Dr. Foote, who is a physicist, began his career in 1911 as a laboratory assistant at the Bureau, and remained there until 1927.

The new panel coordinator was born March 27, 1888. He received a B.A. degree from Western Reserve University, an M.A. degree from the University of Nebraska, and his Ph. D. from the University of Minnesota. Following his early appointment by the Bureau, Dr. Foote was associated with the Gulf Oil Corp. from 1927 to 1953, retiring as vice president and director of research. His appointment as Assistant Secretary of Defense for Research and Engineering followed in 1953. Dr. Foote retired from this public service in 1958 with citations for outstanding service to national security and the Defense Department's Meritorious Civilian Service Award.

Dr. Foote is a past president of the American Physical Society, a member of the National Academy of Science and past chairman of its Engineering Section, a past secretary of the American Philosophical Society, and is active in many technical organizations. In addition to the recently awarded Defense Department citations, many professional honors have been given Dr. Foote, among them the Pittsburgh Award of the American Chemical Society in 1954; an honorary Doctorate of Science from Carnegie Institute of Technology, 1953; the Pittsburgh Junior Chamber of Commerce Award, 1953; and a gold medal for outstanding achievement from the University of Minnesota, 1951.

The NAS-NRC, a nongovernment organization of the nation's leading research scientists, dedicated to the furtherance of science and its use for the common welfare, is specifically authorized by Congress to advise the Federal Government, upon request, on scientific and technical matters. Approximately two years ago, the NAS-NRC requested a number of the major scientific societies of the United States to nominate representatives to serve on the Technical Advisory Panels by which the NAS-NRC furnishes advice and guidance to the Bureau. These panels have aided in keeping the Bureau informed as to the nation's scientific and technical needs, have evaluated the Bureau's work in the light of these needs; and at the same time have pro-

vided an effective link whereby scientists and engineers of the country have gained increased awareness of the Bureau's scientific contributions and of its available scientific services.

Organizations participating in the NAS-NRC Technical Advisory Panels to the National Bureau of Standards include: American Ceramic Society; American Chemical Society; American Institute of Chemical Engineers; American Institute of Electrical Engineers; American Institute of Mining, Metallurgical, and Petroleum Engineers; American Institute of Physics; American Society of Civil Engineers; American Society of Mechanical Engineers; Conference Board of Mathematical Sciences; and Institute of Radio Engineers.

Two Technical Advisory Committees Established

TWO NEW Technical Advisory Committees have been established by the Bureau, one on Calibration and Measurement Services, and one on Engineering and Related Standards.

The committees include leaders in specialized fields, drawn from industry. The purpose of the committees is to aid the Bureau in cooperating with industry in the fields of precision measurement, calibration, and standard practices.

William Wildhack, Special Assistant to the NBS Director, is Chairman of both committees.

The Advisory Committee on Calibration and Measurement Services is an outgrowth of the tremendous increase in measurement and calibration activity in private industry and the military services in the last two years. The "space age" industries have led this growth, along with computer, microwave component, and electronic industries. Numerous studies and surveys conducted by industry and the military show pressing needs for expanded calibration facilities, improved standards, and more and better measuring equipment.

As a step toward answering these needs, standards laboratories have greatly increased in size and numbers throughout the military services and the industries involved. These laboratories perform secondary calibration services; the Bureau provides master standards for calibration, and guides and assists industry and the military in putting their own standards operations on a broader and more systematic basis.

To facilitate liaison between the Bureau and industry, the Advisory Committee on Calibration and Measurement Services has been established. It will advise the Bureau concerning current and anticipated needs of industry for measurements and calibration services, facilitating an understanding of the extent and relative urgency of these needs and suggesting how the Bureau's skills and resources may best be utilized toward meeting them.

Committee members appointed by the Director of the Bureau from among the measurement experts suggested by industry groups, are:

Mr. C. H. Brumley, Director, Electronics & Measuring Instruments, Research and Development, Bausch & Lomb Inc., Rochester 2, N.Y.

Col. William J. Darmody, USA (Ret.), Technical Consultant, The Sheffield Corp., P.O. Box 893, Dayton, Ohio.

Mr. L. H. LaForge, Jr., Staff Specialist, Components and Reliability, Sylvania Electronics Systems, 63 Second Ave., Waltham 54, Mass.

Mr. H. C. Biggs, Manager, Physical and Electrical Standards Department, Sandia Corp., Albuquerque, N. Mex.

Mr. E. J. Brazill, Manager, Quality Laboratories, The Martin Co., Baltimore 3, Md.

Mr. A. J. Woodington, Test Lab Group Engineer, Engineering Standards Laboratory, Convair Astronautics, San Diego 12, Calif.

Dr. William G. Amey, Manager, Research Division, Leeds & Northrup Co., Dickerson Road, North Wales, Pa.

Dr. Ivan G. Easton, Vice President for Engineering, General Radio Co., West Concord, Mass.

Mr. L. B. Wilson, Chief, Primary Standards and Measurements, Sperry Gyroscope Co., Great Neck, N.Y.

Members were selected on the basis of their broad personal knowledge of the measurement problems being encountered in a particular segment of industry and will serve as representatives of the industry rather than of a single firm or association.

The Advisory Committee on Engineering and Related Standards will concern itself with national needs for such standards as codes, specifications, standard test methods, and standard data on the properties of engineering materials; maintaining awareness of the efforts of private organizations in these areas; fostering cooperative programs and recommending uses of the Bureau's special competence for the development and application of engineering and related standards.

Membership consists of six representatives, three each from the American Standards Association and the American Society for Testing Materials, appointed by the Director of the Bureau from nominations made by the two societies. Committee members are:

From the American Standards Association

Mr. John R. Townsend, Special Assistant to the Director of Research and Engineering, Department of Defense, Washington 25, D.C.

Vice Admiral George F. Hussey, Jr., USN (Ret.), Managing Director, American Standards Assoc., 10 E. 40th St. New York 16, N.Y.

Mr. John W. McNair, Technical Director, American Standards Assoc., 10 E. 40th St. New York 16, N.Y.

From the American Society for Testing Materials

Mr. N. L. Mochel, Manager of Metallurgical Engineering, Westinghouse Electric Corp., Philadelphia 13, Pa.

Mr. F. L. LaQue, Vice President, Manager of Development and Research, The International Nickel Co., Inc., 67 Wall St., New York 5, N.Y.

Dr. A. A. Bates, Vice President for Research and Development, Portland Cement Assoc., 33 W. Grand Ave., Chicago 10, Ill.

The two new committees, which will advise on Bureau-wide programs, are in addition to a group of technical advisory panels drawn from leading professional scientific and engineering societies to advise various technical divisions of the Bureau. These panels, whose activities are coordinated by the National Academy of Sciences-National Research Council, help to keep the Bureau informed of the needs of the Nation's scientific and technological community in areas of interest to their professions. (See p. 15.)

Announcement of New Publication:

Precision Measurement and Calibration

ADVANCE orders are now being accepted by the U.S. Government Printing Office for NBS Handbook 77, a compilation of the Bureau's more important publications dealing with precision measurement and the calibration of standards. These publications were originally issued over a period of years as circulars, research papers, chapters of books, and articles in scientific periodicals. As separate documents in the past they best served the needs of scientists working in specialized fields of measurement. Now, however, the tremendous increase in industrial activity, particularly in the missile and satellite field, has led to an unprecedented demand for precision measurement, which, in turn, is bringing about the creation of hundreds of new standards laboratories. Most of these new laboratories must cover the entire field of measurement, and must do so with a staff not previously trained in work on standards. Hence it is necessary to provide pertinent published information in convenient form as quickly as it is practical to do so.

To meet this demand the Bureau has selected those publications that have been referred to most frequently in conferences between Bureau staff members and persons who are engaged in establishing new standards laboratories. The compilation comprises three volumes as follows:

Volume I—Electricity and Electronics—845 pages, $6.00

Volume II—Heat and Mechanics—965 pages, $6.75

Volume III—Optics, Meterology, and Radiation—1,025 pages, $7.00

These three volumes, extensive as they are, include only a fraction of the published work of the Bureau relating to standards. Many of the papers that are reprinted contain extensive bibliographies which will enable the scientist or engineer who is confronted with a special problem to locate additional publications both by the Bureau and from other sources that bear on his problem.

The three-volume set will constitute a handbook for workers in the field of standards comparable to the familiar handbooks of chemistry, physics, and engineering. Also, it will serve as a reference and textbook for hundreds of young scientists and engineers who must acquire training in the shortest possible time to fill responsible positions in new standards laboratories.

Orders should be sent to: Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

UNITED STATES
GOVERNMENT PRINTING OFFICE
DIVISION OF PUBLIC DOCUMENTS
WASHINGTON 25, D.C.

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE TO AVOID
PAYMENT OF POSTAGE, $300
(GPO)

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Volume **45**, No. 12, December 1960. 15 cents. Annual subscription: $1.50, 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Basic Radio Propagation Predictions for March 1961. Three months in advance. CRPL–D196, issued December 1960. 15 cents. Annual subscription $1.50, 50 cents additional for foreign mailing. Avialable on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section A, Physics and Chemistry, Volume **65A**, No. 1, January-February 1961.

Faint lines in the arc spectrum of iron (Fe I). C. C. Kiess, V. C. Rubin, and C. E. Moore.

Infrared absorption of spectra of some 1-acetamido pyranoid derivatives and reducing acetylated pyranoses. R. S. Tipson and H. S. Isbell.

Monolayers of linear saturated succinate polyesters and air-liquid interfaces. W. M. Lee, J. L. Shereshefsky, and R. R. Stromberg.

Heat of formation of beryllium chloride. W. H. Johnson and A. A. Gilliland.

Heat of decomposition of potassium perchlorate. W. H. Johnson and A. A. Gilliland.

Heats of formation of lithium perchlorate, ammonium perchlorate, and sodium perchlorate. A. A. Gilliland and W. H. Johnson.

Heat of formation of N-dimethylaminodiborane. W. H. Johnson, I. Jaffe, and E. J. Prosen.

Separation of hafnium from zirconium by anion exchange. J. L. Hague and L. A. Machlan.

Reaction of sulfur, hydrogen sulfide, and accelerators with propylene and butadiene. F. J. Linnig, E. J. Parks, and L. A. Wall.

Section C, Engineering and Instrumentation, Volume **65c**, No. 1, January-March 1961.

Electronic scanning microscope for a spectrographic plate comparator. M. L. Kuder.

Viscoelastometer for measurement of flow and elastic recovery. R. J. Overberg and H. Leaderman.

An ultra low frequency bridge for dielectric measurements. D. J. Scheiber.

The ephi system for VLF direction-finding. G. Hefly, R. F. Linfield, and T. L. Davis.

Fast counting of alpha particles in air ionization chambers. Z. Bay, F. D. McLernon, and P. A. Newman.

X-ray diffraction measurement of intragranular misorientation in alpha brass subjected to reverse plastic strain. C. J. Newton and H. C. Vacher.

Enthalpy and specific heat of nine corrosion-resistant alloys at high temperatures. T. B. Douglas and A. C. Victor.

Determination of minor constituents in low-alloy steels by X-ray fluorescence. R. E. Michaelis, R. Alvarez, and B. A. Kilday.

Section D, Radio Propagation. Volume **65D**, No. 1, January–February 1961.

Incoherent scattering by free electrons as a technique for studying the ionosphere and exosphere: some observations and theoretical considerations. K. L. Bowles.

Radio wave absorption of several gases in the 100 to 117 kMc/s frequency range. C. O. Britt, C. W. Tolbert, and A. W. Straiton.

On the theory of diffraction by a composite cylinder. R. D. Kodis.

An atlas of oblique-incidence ionograms (a digest). V. Agy, K. Davies, and R. Salaman.

A new approach to the mode theory of VLF propagation. J. R. Wait.

East-west effect on VLF mode transmission across the earth's magnetic field. D. Dobrott and A. Ishimaru.

Magneto-ionic propagation phenomena in low- and very-low-radiofrequency waves reflected by the ionosphere. J. R. Johler.

Correlation of monthly median transmission loss and refractive index profile characteristics. B. R. Bean and B. A. Cahoon.

Characteristics of waveguides for long-distance transmission. A. E. Karbowiak and L. Solymar.

Useful radiation from an underground antenna. H. A. Wheeler.

Observation of *F*-layer and sporadic-*E* scatter at VHF in the Far East. K. Miya, T. Sasaki, and M. Ishikawa.

A high-resolution rapid-scan antenna. H. V. Cottony and A. C. Wilson.

Nonperiodicals

Amplitude probability distributions for atmospheric radio noise, W. Q. Crichlow, A. D. Spaulding, C. J. Roubique, and R. T. Disney. NBS Mono. 23 (1960) 20 cents.

Building code requirements for reinforced masonry, NBS Handb. H74 (1960) 15 cents.

Technical Notes

The following Technical Notes are available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (Order by PB number).

Quarterly radio noise data—December, January, February 1959–60, W. Q. Crichlow, R. D. Disney, and M. A. Jenkins. NBS TN18–5 (PB151377–5) (1960) $1.75.

Quarterly radio noise data—March, April, May 1960, W. Q. Crichlow, R. D. Disney, and M. A. Jenkins. NBS TN18–6 (PB151377–6) (1960) $1.75.

On the nature of the crystal field approximation, H. Goldberg and C. Herzfeld. NBS TN67 (PB161568 (1960) $2.50.

Some experiments on the deposition of gases at 4.2° K, T. Baurer. NBS TN 73 (PB161574) (1960) $1.00.

Scattering of cobalt–60 gamma radiation in air ducts, C. Eisenhauer. NBS TN74 (PB161575) (1960) 75 cents

Soviet research in field electron and ion emission, 1955–1959; an annotated bibliography, T. W. Marton and R. Klein. NBS TN75 (PB161576) (1960) $1.25.

Oblique incidence receiving antenna array for a relative ionospheric opacity meter, A. C. Wilson. NBS TN78 (PB161579) (1960) 50 cents.

U.S. GOVERNMENT PRINTING OFFICE: 1961 O—578342